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EFFECT OF CHANGES IN AILERON RIGGING ON THE STICK FORCES OF A HIGH-SPEED FIGHTER AIRPLANE

By Harry E. Murray and S. Anne Warren

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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EFFECTS OF CHANGES IN AILERON RIGGING ON THE STICK FORCES OF A HIGH-SPEED FIGHTER AIRPLANE

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SUMMARY

The effects of changes in aileron rigging between 2° up and 2° down on the stick forces were determined from wind-tunnel data for a finite-span wing model. These effects were investigated for ailerons deflecting equally in both directions and linearly with stick deflection. Data were analyzed for a Frise, a sealed internally balanced, and a beveled-trailing-edge aileron. The results of the analysis showed that only ailerons having linear hinge-moment characteristics are unaffected by changes in rigging and indicated that ailerons having decidedly nonlinear hinge-moment-coefficient curves, particularly for deflections near 0°, are very sensitive to changes in rigging.

INTRODUCTION

For certain types of aileron, changes in rigging are known to have a pronounced effect on the stick-force characteristics. In order to investigate the effect of changes in rigging on stick-force characteristics, data have been analyzed for three types of balanced aileron - Frise, internally balanced, and beveled trailing edge. These ailerons were tested on a rigid, finite-span wing model and the data are directly comparable since the same test setup was used for the three ailerons.

The stick-force characteristics were estimated for the ailerons installed on a high-speed fighter airplane having the following characteristics:

Wing loading, pounds per square foot	40
Span, feet	40
Aspect ratio	7.3
Taper ratio	0.42
Aileron root-mean-square chord, feet	1.563
Aileron span, feet	9.4
Aileron chord, percent wing chord	20
Slope of section lift curve, per degree	0.103
Maximum aileron deflection, degrees	±12
Maximum stick deflection, degrees	±22
Stick length, feet	2.00

The aileron was located between 50.9 and 98.0 percent of the semispan. It should be emphasized that only the effect of changes in rigging is considered and that other factors may have important effects on the stick-force characteristics of any of the ailerons investigated.

SYMBOLS AND PARAMETERS

F_s stick force, pounds

$pb/2V$ helix angle of airplane in roll, radian

V_i indicated airspeed, miles per hour

δ aileron deflection, degrees

C_h aileron hinge-moment coefficient $\left(\frac{H}{q\bar{c}_a{}^2 b_a}\right)$

$C_l{}'$ rolling-moment coefficient; referred to wind axes $\left(\frac{L}{qbS}\right)$

c wing chord at any spanwise station

c_a aileron chord measured along airfoil chord line

$\bar{c}_a$ root-mean-square chord of aileron

α angle of attack, degrees

C_L lift coefficient $\left(\frac{L}{qS}\right)$

ϕ trailing-edge angle, degrees

H	hinge moment
q	dynamic pressure
L	lift
S	area of wing, square feet
b	wing span
b_a	aileron span

RESULTS AND DISCUSSION

The effect of angle of rig on the position of the ailerons relative to the wing with stick neutral is shown in figure 1. The investigation of the effect of changes in rigging on stick force is based on the hinge-moment-coefficient curves shown in figures 2, 3, and 4, which are taken from figures A23(b), C58, and D33, respectively, of reference 1. Because reference 1 gives hinge-moment characteristics for the internally balanced aileron at only one angle of attack ($\alpha = 1.00^{\circ}$), curves for other angles of attack were estimated by applying values (obtained from reference 2) for the change in hinge-moment coefficient with angle of attack. Stick-force characteristics were then estimated by the method described in reference 3 and the results plotted in figures 5 to 7.

The stick force of the Frise aileron tested is very sensitive to changes in rigging, as shown in figure 5. This aileron can, between an angle of uprig of 2° and an angle of downrig of 2°, be either light or very heavy. It appears that, in general, within a range of angle of rig of 4°, Frise ailerons may be heavy, light, or even overbalanced.

The sealed internally balanced aileron is insensitive to changes in rigging (fig. 6), except at large helix angles corresponding to the nonlinear part of the hinge-moment-coefficient curve. At $\frac{pb}{2V} = 0.10$, for example, the stick-force varies about 10 pounds for a range of angle of rig of 4°.

For beveled-trailing-edge ailerons, variation of stick force with angle of rig (fig. 7) is small compared with the variation for Frise ailerons. A 5-pound variation does result, however, at $\frac{pb}{2V} = 0.01$ and overbalance might occur on an airplane having similar but more closely balanced ailerons.

A comparison of the results in figures 5 to 7 with the basic hinge-moment-coefficient curves of figures 2 to 4 indicates that only ailerons having linear hinge-moment characteristics are unaffected by changes in rigging and that ailerons having decidedly nonlinear hinge-moment-coefficient curves, particularly for deflections near 0°, are very sensitive to changes in rigging. Only ailerons deflecting equally in both directions and linearly with stick deflection are considered herein. Information on effects of changes in rigging with a differential linkage is given in references 4 and 5.

When an aileron which is sensitive to changes in rigging is used, it should be remembered that changes in angle of rig as high as 4° have been reported in flight as a result of elastic deformation in the wing, aileron, or control system. Such deformations usually uprig the ailerons because ailerons generally tend to float upward, particularly under the conditions of heavy loading that occur during pull-outs. Frise ailerons, which become light when uprigged, may therefore overbalance. Temperature changes may also affect the angle of rig if push rods having coefficients of thermal expansion different from that of the wing structure are used. These variations from design rigging that occur in flight may cause marked variations from the design stick-force characteristics when an aileron sensitive to changes in rigging is used.

CONCLUSIONS

An analysis of the effects of changes in aileron rigging on the stick-force characteristics of a high-speed fighter airplane with ailerons having three types of balance indicated the following conclusions:

1. The Frise aileron was very sensitive to changes in rigging, the beveled-trailing-edge aileron was relatively insensitive, and the sealed internally balanced aileron was insensitive except at large helix angles corresponding to the nonlinear part of the hinge-moment-coefficient curve.

2. Only ailerons having decidedly nonlinear hinge-moment-coefficient curves, particularly at aileron deflections near 0°, were sensitive to changes in rigging.

3. Variations from design rigging that occur in flight as a result of elastic deformation or possibly from temperature effects in the structure may cause a marked variation from the design stick-force characteristics when an aileron sensitive to changes in rigging is used.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va.

REFERENCES

1. Rogallo, F. M.: Collection of Balanced-Aileron Test Data. NACA ACR No. 4A11, 1944.

2. Rogallo, F. M., and Lowry, John G.: Résumé of Data for Internally Balanced Ailerons. NACA RB, March 1943.

3. Swanson, Robert S., and Toll, Thomas A.: Estimation of Stick Forces from Wind-Tunnel Aileron Data. NACA ARR No. 3J29, 1943.

4. Rogallo, F. M., and Purser, Paul E.: Wind-Tunnel Investigation of a Plain Aileron with Various Trailing-Edge Modifications on a Tapered Wing. I - Aileron with Fixed Inset Tabs. NACA ARR, Sept. 1942.

5. Jones, Robert T., and Nerken, Albert I.: The Reduction of Aileron Operating Force by Differential Linkage. NACA TN No. 586, 1936.

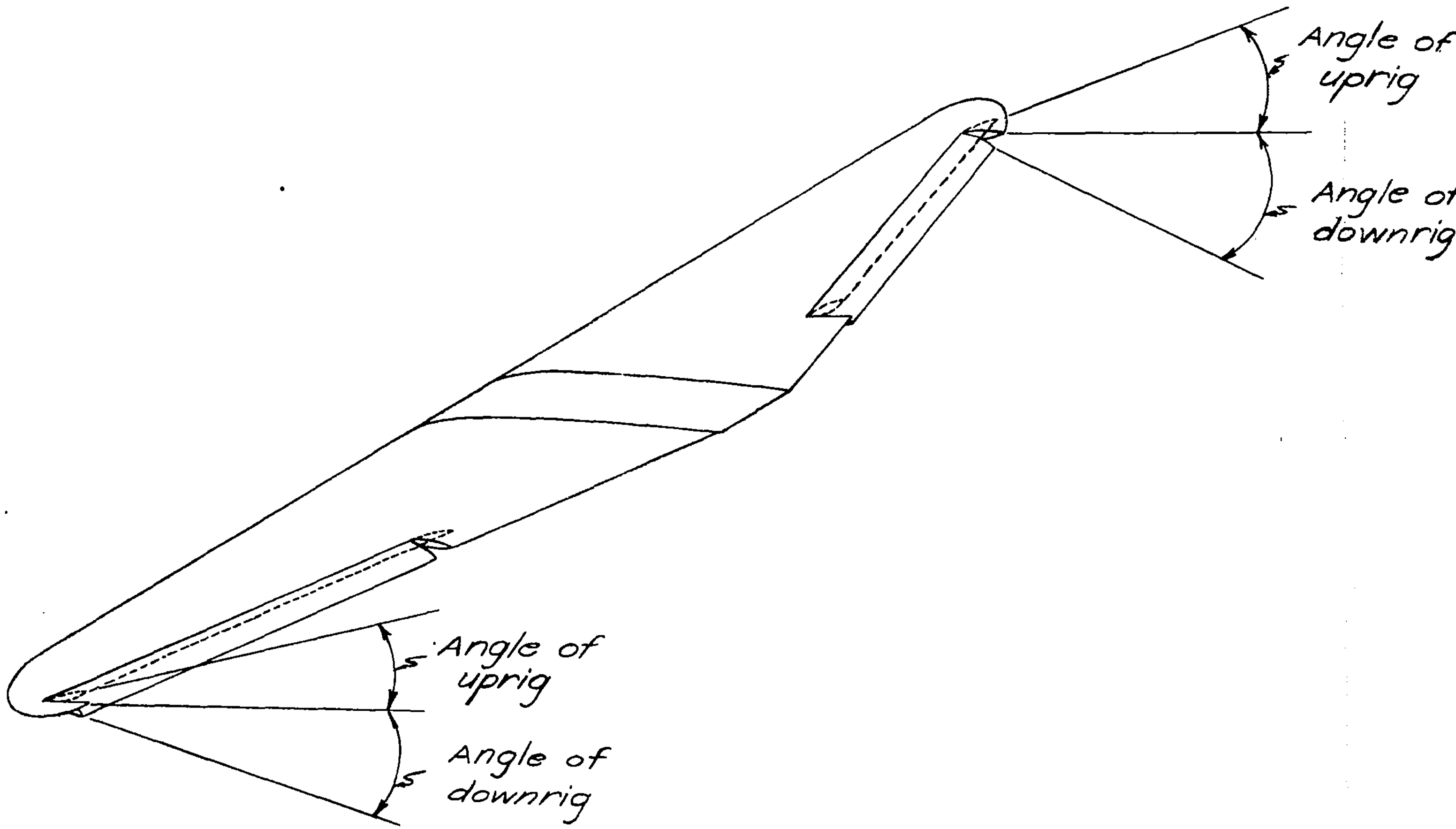

Figure 1.- Uprigged and downrigged ailerons on the wing of a modern high-speed fighter airplane.

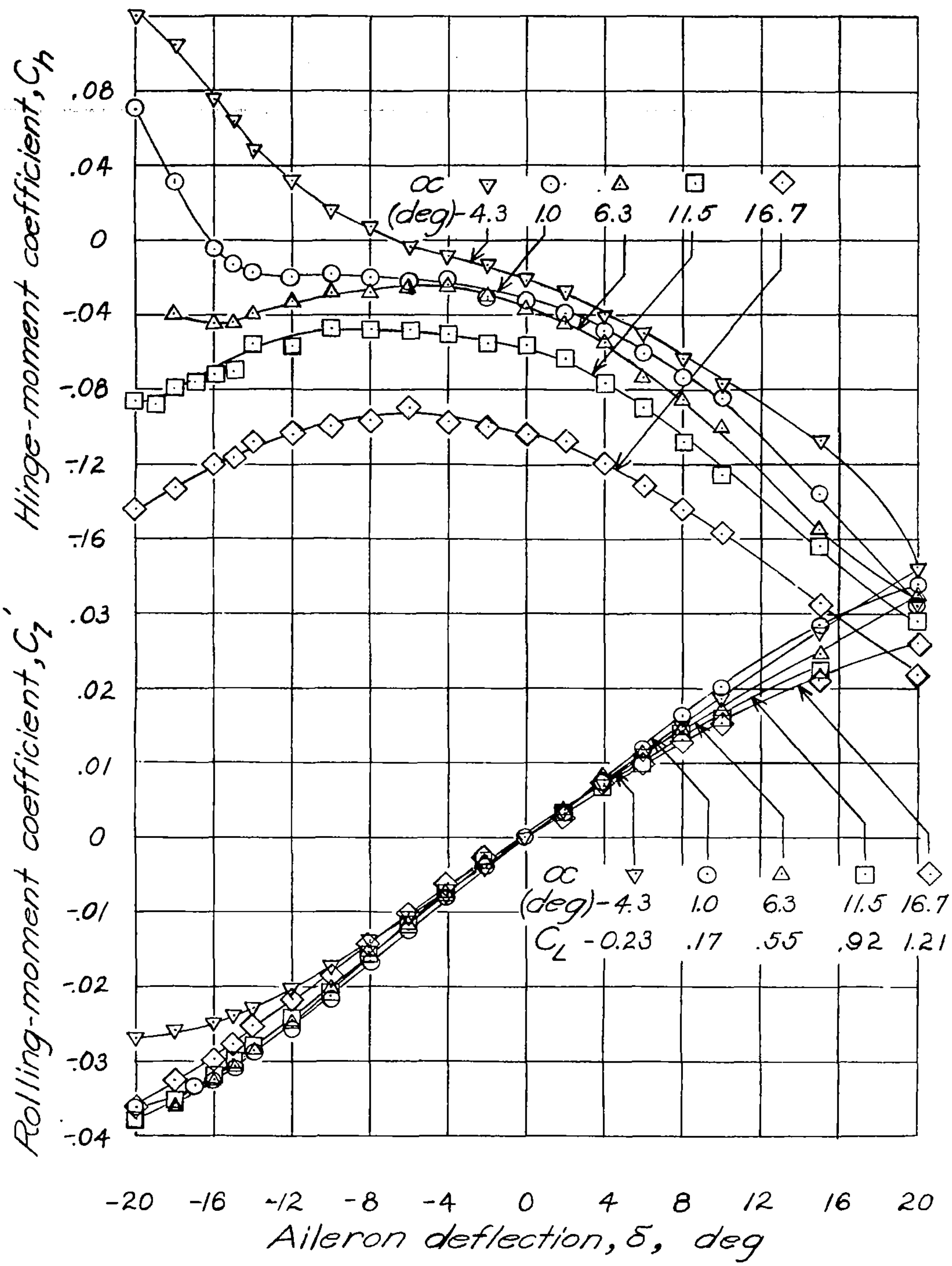

Figure 2.- Characteristics of Frise aileron with $0.40c_a$ balance on 0.4-scale model of tapered low-drag wing.

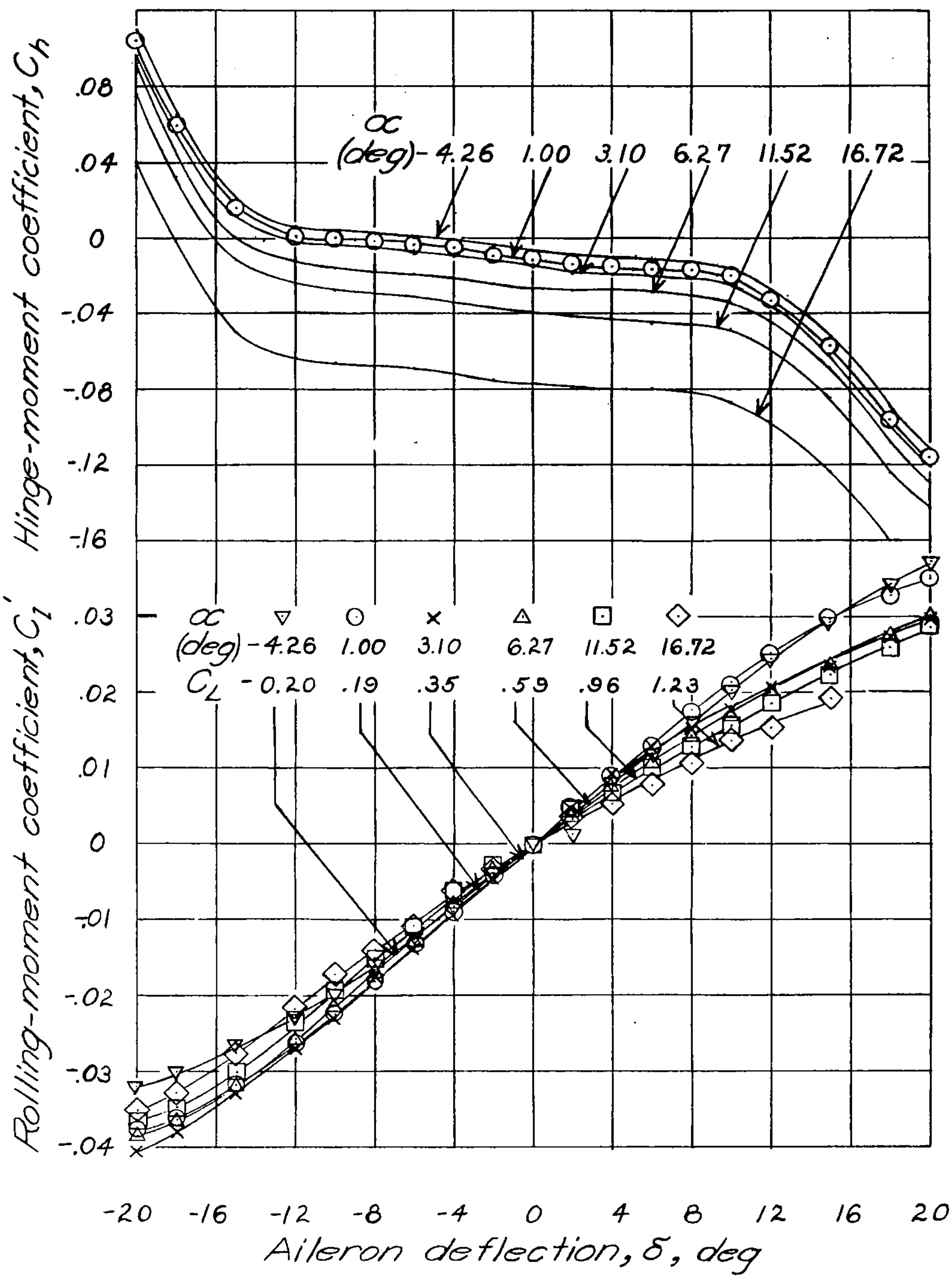

Figure 3.- Characteristics of internally balanced aileron with $0.45c_a$ balance on 0.4-scale model of tapered low-drag wing. Balance completely sealed.

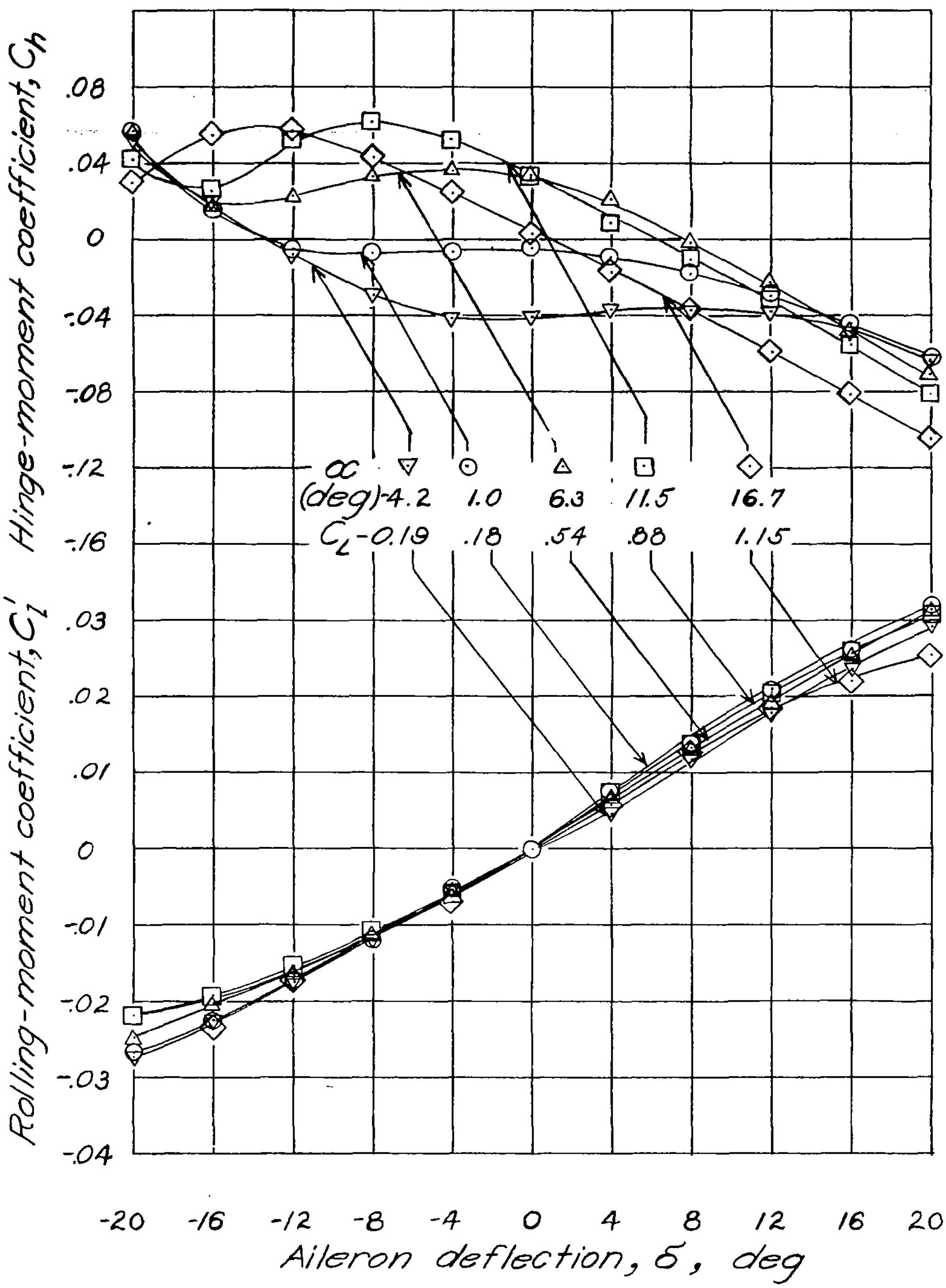

Figure 4.- Characteristics of beveled-trailing-edge aileron with $0.30c_a$ bevel on 0.4-scale model of a tapered low-drag wing ϕ, 31.0°; no seal; 0.002c gap.

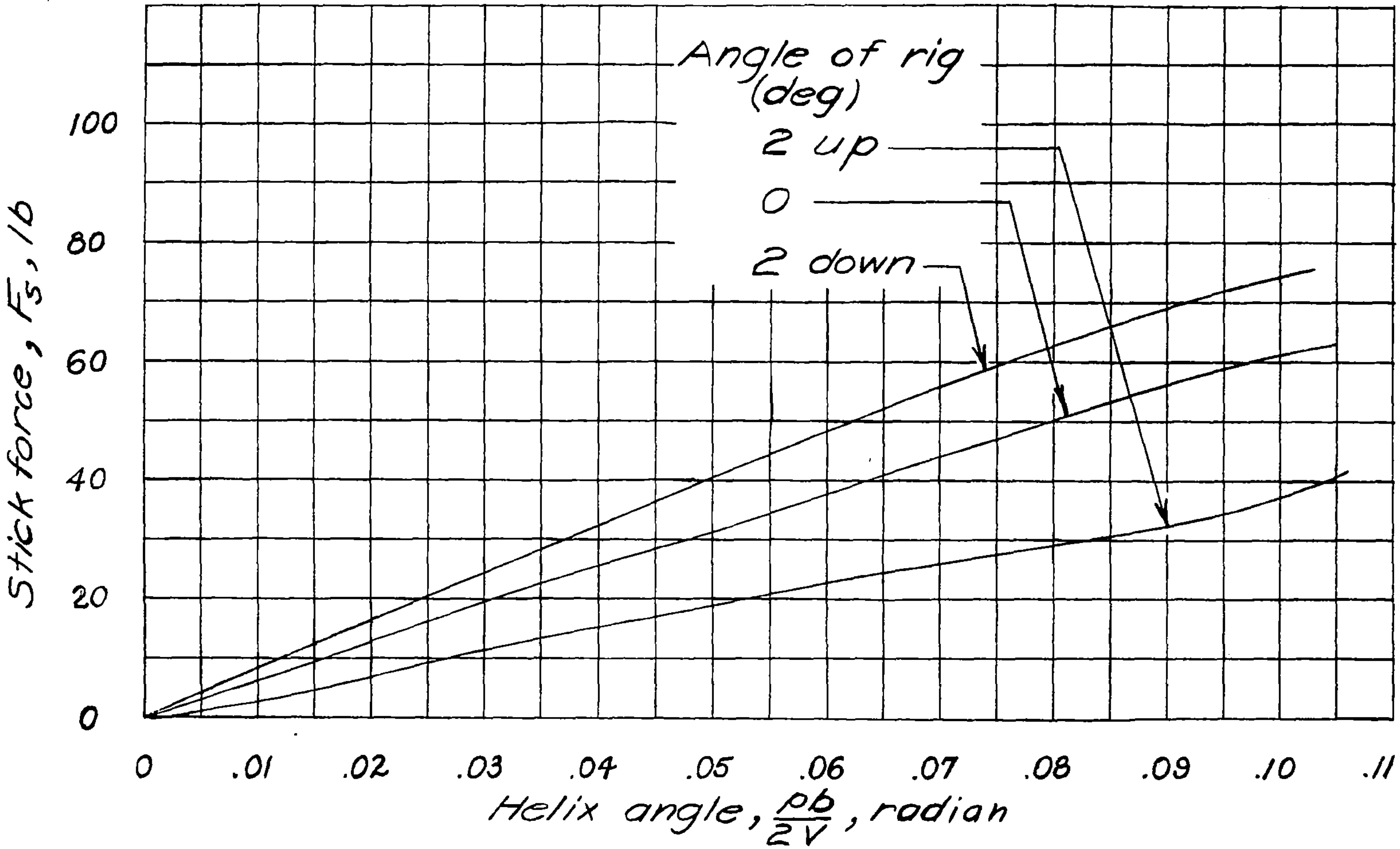

Figure 5.- Stick-force characteristics of high-speed fighter airplane having Frise ailerons with $0.40c_a$ balance and three angles of rig. V_i, 300 mph.

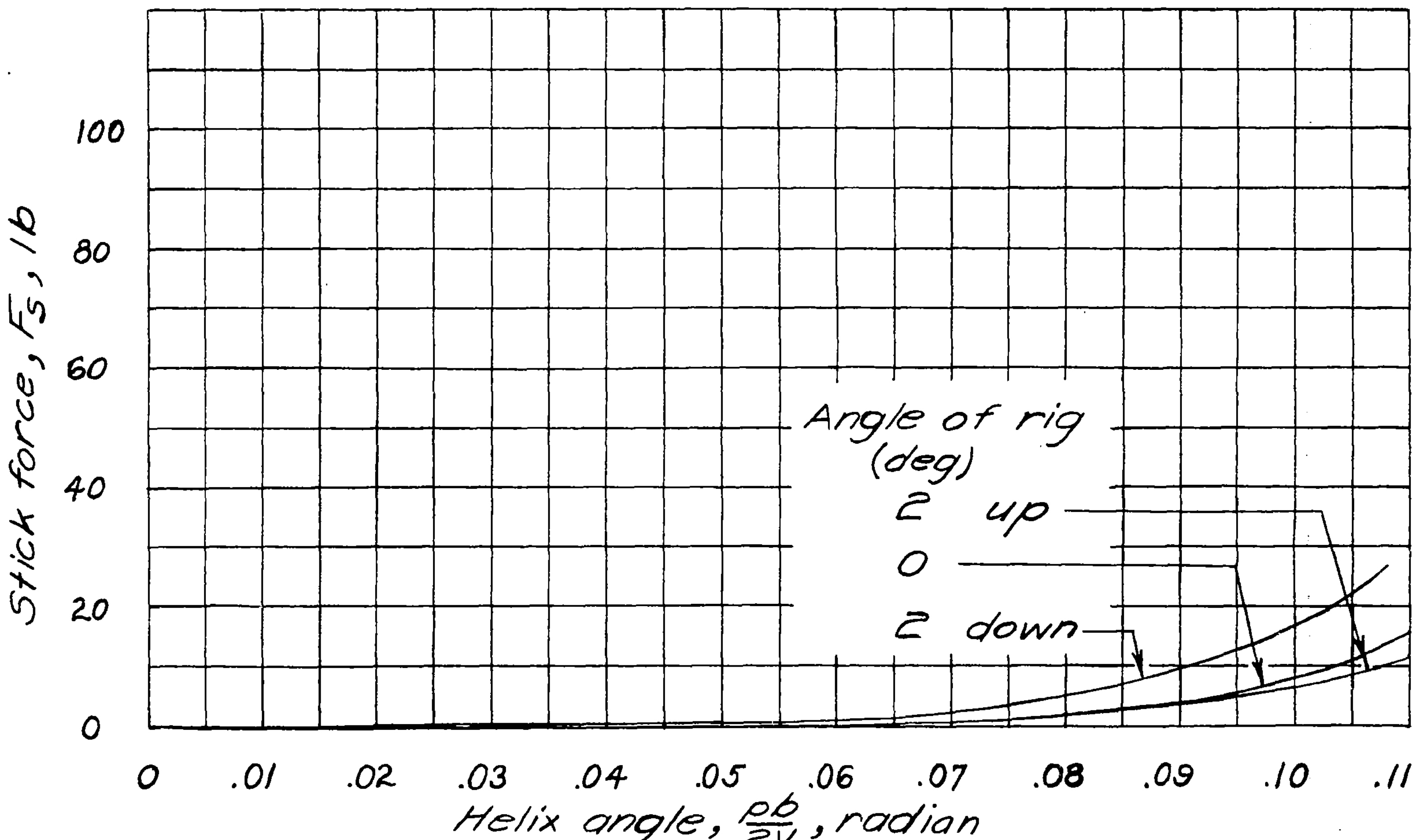

Figure 6.- Stick-force characteristics of high-speed fighter airplane having sealed internally balanced ailerons with $0.45c_a$ balance and three angles of rig. V_i, 300 mph.

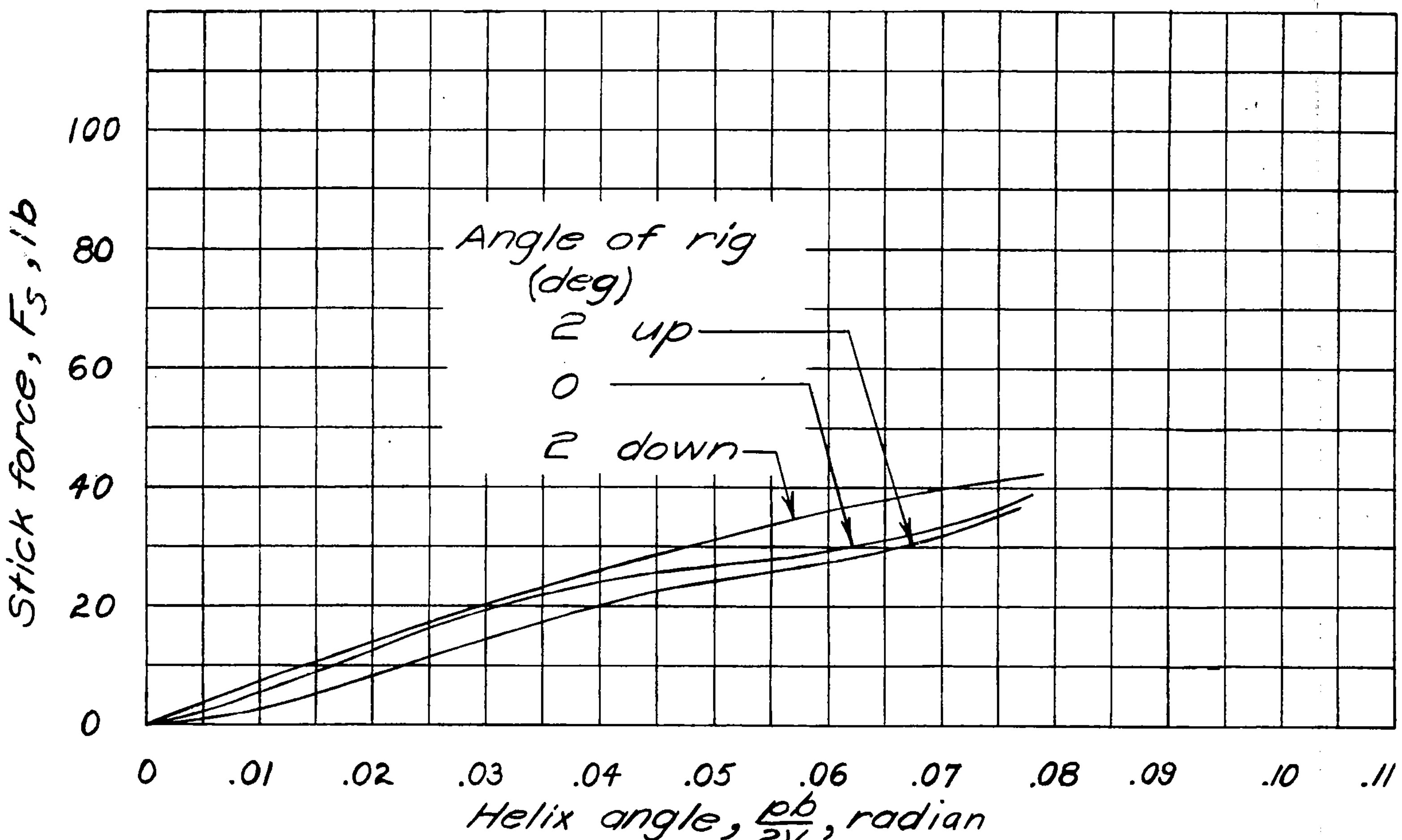

Figure 7. - Stick-force characteristics of high-speed fighter airplane having beveled-trailing-edge ailerons with $0.30c_a$ bevel and three angles of rig. ϕ, 31.0°; 0.002c gap; V_i, 300 mph.